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HEAT LOSSES IN A TUNNEL KILN FOR BRICK FIRING

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The results of experimental studies of heat losses via the enclosing structures of an operating brick-firing kiln using a thermal imager are described.

Fuel consumption in firing comprises 80 – 85% of total fuel consumed in brick production. Therefore, it is essential to lower energy consumption in order to reduce production cost.

Energy-saving measures at brick-firing kilns are oriented in three directions:

– upgrade of kilns and implementing scientifically substantiated firing conditions by automating the firing process and using state-of-the art gas burners with automatic control of gas : air ratio.

– rational utilization of waste heat, i.e., recovering the heat of flue gases and hot air from the cooling zone of the kiln;

– improving the thermal insulation of kilns and kiln car lining.

The present paper describes the results of an experimental study of thermal losses via the enclosing structures of a brick-firing kiln:

The temperature fields of the enclosure structures of the tunnel brick-firing kiln at the Altair Works of Construction Materials have been determined using a Thermasam PM 695 thermal imager (U.S.).

The kiln at the Al'tair Works has 48 zones and a forechamber. All zones were investigated from the sides and from the top and the data on each zone were recorded.

The tunnel furnace is designed as a straight channel formed by the walls and a flat roof made of assembled refractory concrete elements. Zones 0 – 5 and 46 – 48 are made of concrete blocks based on cement grade 25, zones 6 – 14 and 34 – 45 are made of claydite-concrete blocks, and zones 15 – 33 have blocks of heavy refractory concrete and claydite-concrete. The thermal insulation of the walls in zones 20 – 38 is made of broached sheets of slag cotton grade 100, which are enclosed on two sides with metallic mesh. The outer surfaces of the walls are faced with building shingle.

A roof made of refractory concrete plates fastened to the ceiling beams encloses from above the kiln channel. The plates are made of two types of concrete; the ribs are made of heavy reinforced concrete and the inserts between them are from lightweight concrete. The joints between the plates are filled with an asbestos-vermiculite mixture. To protect the load-carrying roof elements from heat radiation, a screen made of roof steel sheets is installed beneath the roof. The blanket elements are heat-insulating cellular concrete plates. The joints between the plates are filled with slag cotton. A layer of concrete (grade 100) 30 mm thick with anti-shrinkage joints is placed on top of the blanket material.

The results of analysis of temperature fields on the outer surfaces of the kiln zones are indicated in Fig. 1. The interpolation method was used to determine the weighted mean temperatures for each kiln zone. It can be seen that the tempera-

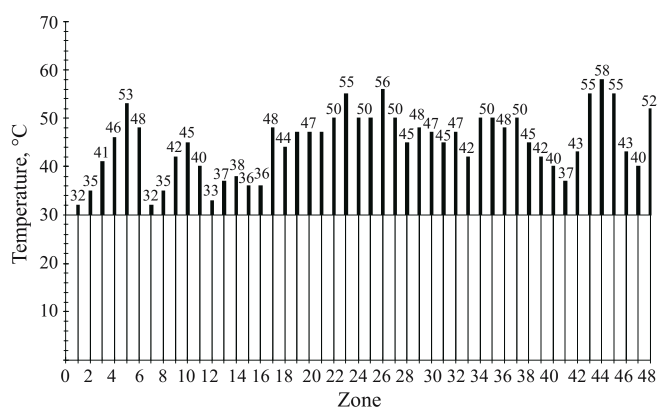

Fig. 1. Weighted mean temperatures of external kiln walls split by zones: 30°C) theoretical temperature of the external surface of the kiln.

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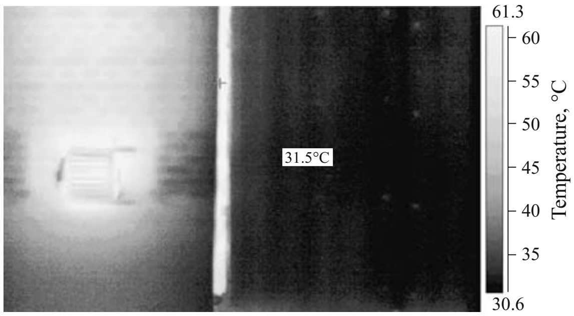

Fig. 2. Thermogram of zone 9 with a brickwork insert fragment.

ture on the outer surfaces of the kiln is above the design values, especially in zones 4 – 6, 22 – 28, and 43 – 45 where heat losses are substantial, which leads to the excessive consumption of energy.

Figures 2 and 3 give examples of thermograms of the exterior walls of the furnace.

The mean temperature of zone 9 is 42°C, that of the brickwork part — 56°C, and of the concrete wall on the right — 31°C. Thus, heat is lost via a large area of brickwork, which points to the insufficient thermal insulation. The thermogram exhibits the heat-loss sector in the form of a slot with a temperature of 61°C in the joint between the brickwork and the concrete wall, i.e., we see a partial nonthrough destruction of the joint.

The mean temperature of the concrete wall in zone 23 is 55°C. It can be seen in the photo that the joint between the concrete blocks and some fragments of thermal insulation have been destroyed.

The mean temperature of the concrete wall in zone 43 is 55°C. There are no destructions, but we can see substantial heat losses via a large area, which points to the insufficient thermal insulation.

We next calculated thermal losses for each zone based on the mean temperatures according to the method described in [1]. Consequently, based on the data from [2] the final formulas for determining heat losses of enclosures have the following form:

$$Q_{\text{tot}} = Q_{\text{w}} + Q_{\text{r}}\,;$$

$$Q_{\text{w}} = (\alpha_{\text{con}} + \alpha_{\text{rad}})(t_{\text{w}} - t_{\text{a}})\,F_{\text{w}}\,;$$

$$Q_{\text{r}} = (\alpha_{\text{con}} + \alpha_{\text{rad}})(t_{\text{r}} - t_{\text{a}})\,F_{\text{w}}\,,$$

where Q_{w} and Q_{r} are the heat losses of the wall and the roof of the kiln; α_{con} is the heat transfer coefficient; α_{rad} is the radiation coefficient; t_{w} and t_{r} are the weighted mean temperatures of the external surfaces of the walls and the roof; F_{w} and F_{r} are the surface areas of the walls and the roof.

In designing the thermal balance of the kiln, heat losses via the enclosing structure should be within 6 – 8% of the total heat losses. Comparing the heat losses determined based on the temperature fields of the outer surfaces of the walls and the roof of the firing kiln to the recommended heat loss level, we found them equal to 12.1% instead of 6 – 8%, which means an excess by about 5% in energy consumption.

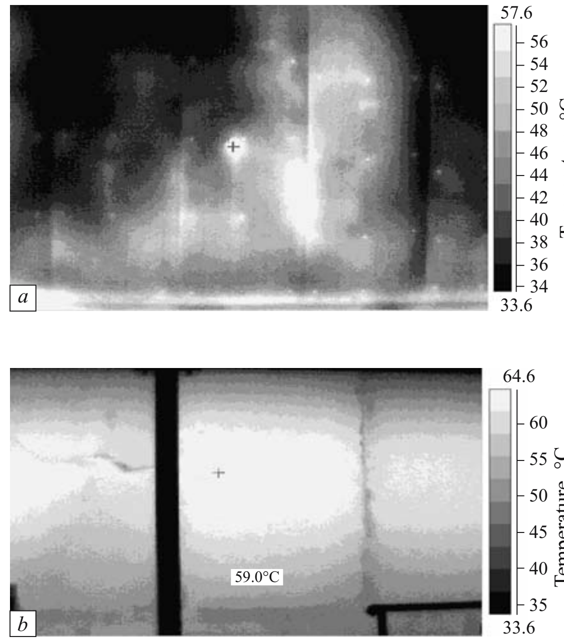

Fig. 3. Thermogram of zones 23 (*a*) and 43 (*b*) made of concrete blocks.

It was found that the destruction of the joint between concrete blocks in firing zones 23, 26, and 27 leads to thermal losses and in preparatory zones 7, 12, 14, and 16 and cooling zones 39, 41, and 47 lead to the inflow of cold air from outside into the kiln, which is determined by the aerodynamic kiln regime. The inflow of cold air would not have been detected in studying the temperature of the outer surfaces, except for the thermal imager, since the temperature of the enclosing surfaces remains unchanged. The non-through destruction of the joint between concrete blocks produces only heat losses in the firing zone, preparatory zone, and cooling zone. The cold air inflow into the kiln chamber has a negative effect on the entire technological process and, accordingly, on brick quality, whereas heat losses cause only excessive energy consumption.

In order to decrease thermal losses via the kiln enclosures, the following measures should be performed: in the case of the crumbling of joints between the plates the kiln lining should be repaired by the plug method using asbestos-vermiculite concrete; if the photo shows destruction of the thermal insulation layer, it must be repaired by the patch method using basalt fiber; in zones where substantial heat losses occur via large areas but the lining and the heat-insulation layer are not disturbed, it is necessary to implement additional thermal insulation using the newest materials based on basalt fiber.

The experimental studies provide the following:

– accuracy in identifying heat loss zones, their sizes and configurations;

– identifying the type of destruction of the enclosing structure or thermal insulation, which would be impossible without breaking the heat-insulating layer if the thermal imager had not been used; this has made it possible to develop justified recommendations for repairing the kiln lining or thermal insulation;

– revealing the need for additional thermal insulation in zones with large heat losses even when the lining or thermal insulation are not destroyed;

– the possibility of saving up to 5% thermal energy, i.e., cutting the consumption of natural gas for brick firing by 27 m^3/h.

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